Poissonian Reducibility and Thermal Scaling in Nuclear Multifragmentation

L. Beaulieu, L. Phair, L.G. Moretto and G.J. Wozniak
Nuclear Science Division, Lawrence Berkeley National Laboratory, Berkeley, California 94720

Several aspects of nuclear multifragmentation may be understood in terms of *nearly independent* fragment emission from multifragmenting sources with *thermal-like* probabilities. It was found [1] that the Z integrated fragment multiplicity distributions are binomially distributed in each transverse energy (E_t) window. The reduced one fragment emission probabilities p give linear Arrhenius plots when $\log 1/p$ is plotted vs $1/\sqrt{E_t}$. If the excitation energy E^* is proportional to E_t and consequently, the temperature T to $\sqrt{E_t}$, these linear Arrhenius plots suggest that p has the Boltzmann form $p \propto \exp(-B/T)$ [1].

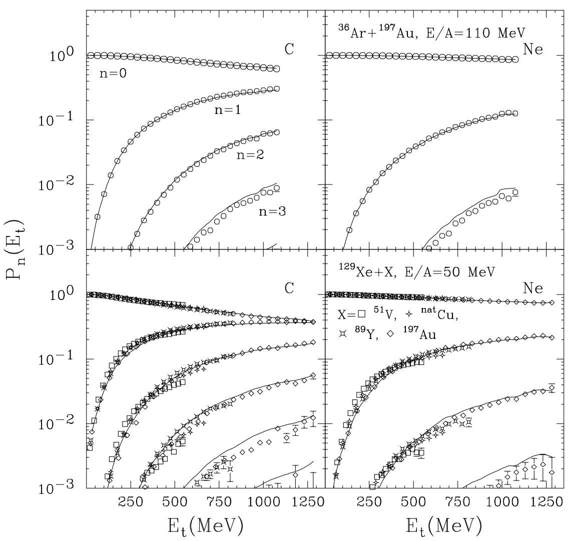

FIG. 1. The excitation functions P_n for carbon emission (left column) and neon emission (right column) from the reactions ^{36}Ar+^{197}Au at E/A=110 MeV (top panels) and ^{129}Xe+^{51}V,^{nat}Cu,^{89}Y,^{197}Au (bottom panels). The lines are a Poisson fit to the gold target data.

In this work [2], we analyze the fragment multiplicity distributions for each individual fragment Z value. This restriction has the rather dramatic effect of decreasing the elementary probability p to the point were the variance over the mean for any Z is very close to one for all values of E_t [1,2]. This is the Poissonian limit. We can verify the quality of the Poissonian fits to the multiplicity distribution in Fig. 1. These Poissonian fits, $P_n(Z) = \frac{\langle n \rangle^n e^{-\langle n \rangle}}{n!}$, are excellent for all Z values starting from Z=3 up to Z=14 over the entire range of E_t and for all the reactions which we have studied. $\langle n_Z \rangle$ is now the only quantity needed to describe the emission probabilities P_n of charge Z. Therefore $\langle n_Z \rangle$ fills the same role as p in the binomial case. Thus we conclude that reducibility (now Poissonian reducibility) is verified at the level of individual Z values for many different systems.

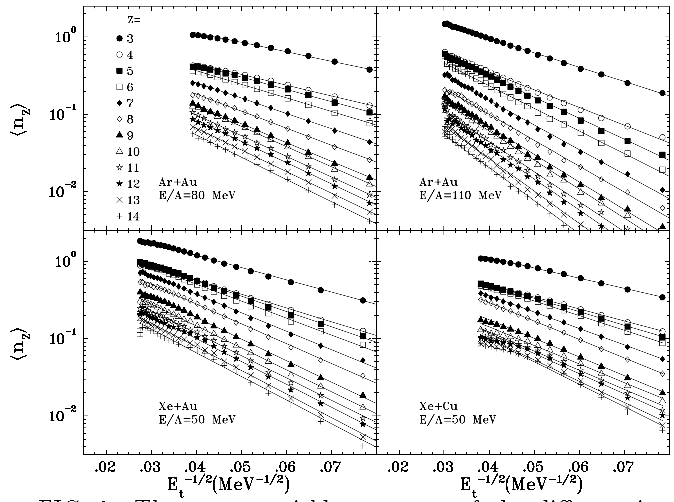

FIG. 2. The average yield per event of the different indicated elements (symbols) as a function of $1/\sqrt{E_t}$ for the indicated reactions. The lines are linear fits to the data.

In order to verify thermal scaling we generate Arrhenius plots by plotting $\log \langle n \rangle$ vs $1/\sqrt{E_t}$. Fig. 2 gives a family of these plots for four different reactions. Each family contains Z values extending from Z=3 to Z=14. The observed Arrhenius plots are strikingly linear over 1 to 2 order of magnitude, and their slopes increase smoothly with increasing Z value. The overall linear trend demonstrates that thermal scaling is also present when individual fragments of a specific Z are considered. The advantage of this procedure is readily apparent. For any given reaction, thermal scaling is verifiable for as many atomic numbers as are experimentally accessible. Poissonian reducibility is tested for each (E_t,Z) couple, or 936 times for Fig. 2. This is an extraordinary level of verification of the empirical reducibility and thermal scaling with the variable E_t.

The experimental observation of Poissonian reducibility means that IMF production is dominated by a stochastic process. Of course stochasticity falls directly in the realm of statistical decay. It is less clear how it would fare within the framework of a dynamical model. Futhermore, the thermal scaling of $\langle n_Z \rangle$ suggest that it has the Boltzmann form $\langle n_Z \rangle \propto \exp(-B_Z/T)$, giving the possibility of extracting a fragmentation "barrier" B_Z for each Z. Finally, the present approach leaves the Arrhenius plots free of distortion or autocorrelation [3].

[1] L.G. Moretto, *et al.*, Phys. Rep. **287**, 249 (1997).
[2] L. Beaulieu *et al.*, LBNL-41075, sub. to Phys. Rev. Lett.
[3] L. Beaulieu *et al.*, contribution to this annual report.